NASA Astrophysics Division

Technology Gaps: Identification, Solicitation, & Enabling Future Missions

Mirror Technologies Workshop 2016

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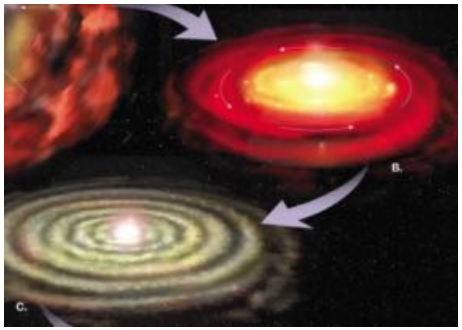
Purpose of Our Technology Gap Assessment

- **Physics of the Cosmos (PCOS) and Cosmic Origins (COR) Program technology gaps identify where and how the current state of the art is insufficient to enable our future strategic missions**
- **This process offers two opportunities:**
  - Submitting technology gaps allows you to help shape future investment potentials and future missions
  - High-priority gaps inform NASA solicitations: submitting proposals in response allows you to help enable strategic missions
- **We will cover:**
  - Overview of our Programs and technology development processes
  - Top priority gaps this year
  - Competed opportunities available
  - Current funded portfolio
  - How you can contribute and engage

NB: "strategic missions" here refers to four concepts identified by NASA HQ APD for consideration in the 2020 Decadal Survey, as well as a possible US contribution to the ESA-led LISA and ATHENA missions, the Inflation Probe, and similar concepts.

Astrophysics Science Themes

The organization of NASA's Astrophysics Division (APD) includes three science themes:



How did we get here?

➔ *Cosmic Origins Program (COR)*

– Program Office at GSFC

How does the universe work?

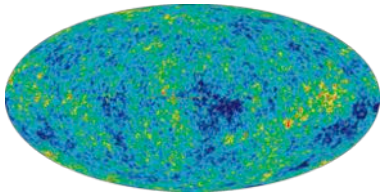
➔ *Physics of the Cosmos (PCOS)*

– Program Office at GSFC

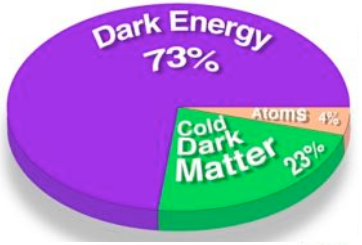
Are we alone?

➔ *Exoplanet Exploration Program (ExEP)*

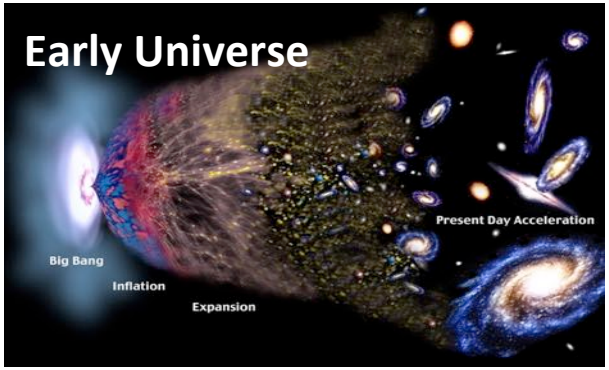
– Program Office at JPL

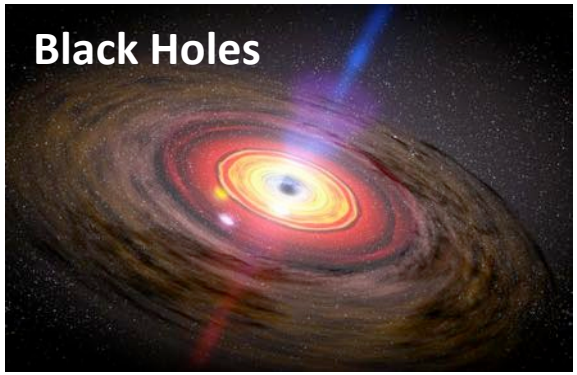


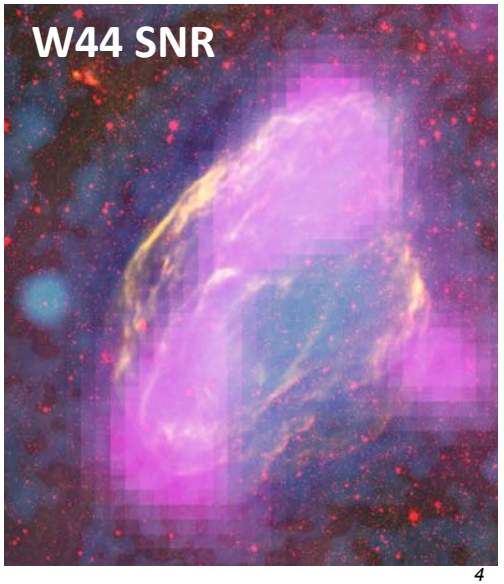
PCOS Science Objectives



- Expand our knowledge of dark energy
- Precisely measure the cosmological parameters governing the evolution of the universe and test the inflation hypothesis of the Big Bang
- Test the validity of Einstein's General Theory of Relativity and investigate the nature of spacetime
- Understand the formation and growth of massive black holes and their role in the evolution of galaxies
- Explore the behavior of matter and energy in its most extreme environments







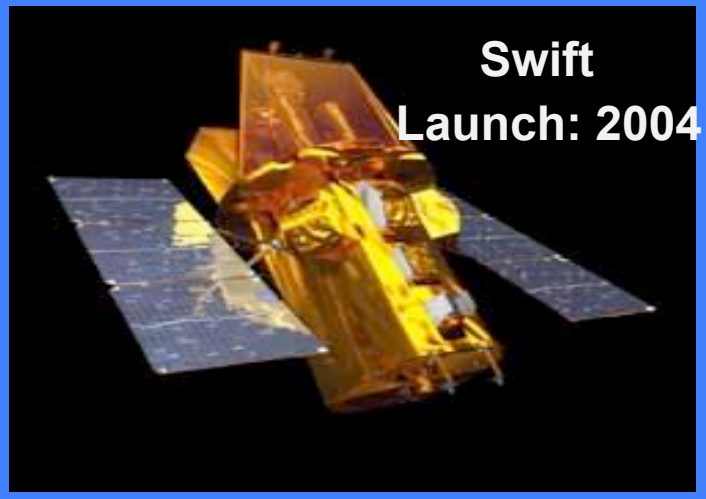
Missions Addressing PCOS Science

Chandra
Launch: 1999

NuSTAR
Launch: 2012

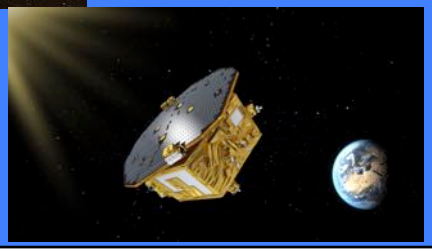
Fermi
Launch: 2008

XMM
Launch: 1999



Swift
Launch: 2004

LPF
Launch: 2015

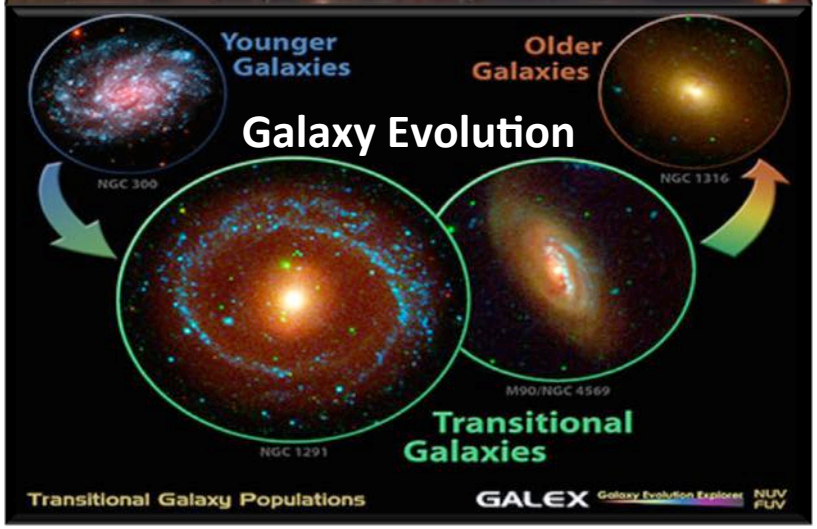


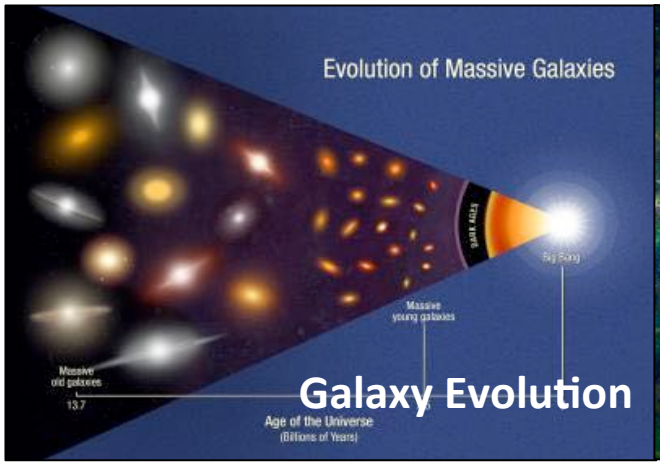
COR Science Objectives

Improve understanding of the many phenomena and processes associated with:

- Galaxy formation and evolution
- Stellar formation and evolution
- Planetary system formation and evolution

from the earliest epochs to today





Missions Addressing COR Science

Four strategic mission studies, plus L3

- **FAR IR Surveyor** – The Astrophysics Visionary Roadmap identifies a Far IR Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.
- **Habitable-Exoplanet Imaging Mission** – The 2010 Decadal Survey recommends that a habitable-exoplanet imaging mission be studied in time for consideration by the 2020 Decadal Survey.
- **Large UV/Optical/IR Surveyor** –The Astrophysics Visionary Roadmap identifies a Large UV/Optical/IR Surveyor as contributing through improvements in sensitivity, spectroscopy, high contrast imaging, astrometry, angular resolution and/or wavelength coverage. The 2010 Decadal Survey recommends that NASA prepare for a UV mission to be considered by the 2020 Decadal Survey.
- **X-ray Surveyor** – The Astrophysics Visionary Roadmap identifies an X-ray Surveyor as contributing through improvements in sensitivity, spectroscopy, and angular resolution.

In addition, NASA is assessing partnership with ESA on the LISA gravitational-wave mission via the L3 Study Team.

NASA's Astrophysics Division Funds All Levels of Technology Maturity

NASA's Astrophysics Division funds technology development via

- **Astrophysics Research and Analysis (APRA) program** solicits basic research proposals relevant to NASA's astronomy and astrophysics programs, from basic principles through flight missions (Technology Readiness Level, TRL, 1 through 3 up to 9). Suborbital investigations (balloons, sounding rockets) are encouraged. 4 or 5 yrs duration awards.
- **Strategic Astrophysics Technology (SAT) program** matures key technologies that address the needs of a specific future mission, taking them from proof of concept through component/breadboard validation in relevant environment (TRL 3 through 5). 2 or 3 years duration awards.
- **Flight projects** address the final maturation stages (TRL 6 through 9) proving the technology's flight-worthiness for a mission-specific application.

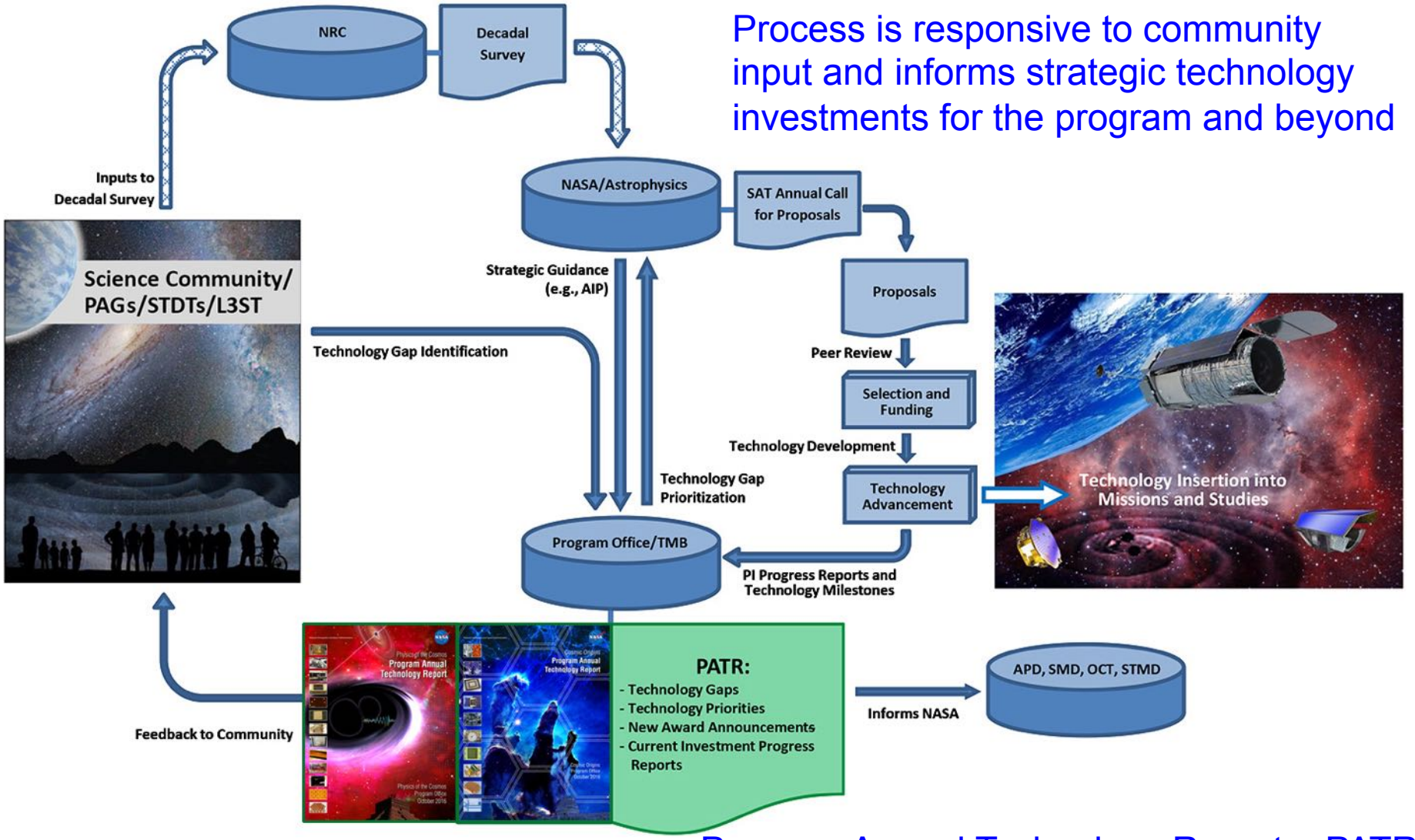
Strategic Astrophysics Technology (SAT)

The SAT Program was established in 2009 to support maturation of mid-TRL technologies. It is organized into 3 elements, one for each of the Division's three science themes. First PCOS and COR SAT solicitations were in 2010.

Solicitation year	PCOS SAT Proposals		Selection Rate
	Submitted	Awarded	
2010	21	5	24%
2011	26	5	19%
2012	10	3	30%
2013	8	6	75%
2014	6	3	50%
2015	9	tbd	0%
Total to Date	80	22	28%

Solicitation year	COR SAT Proposals		Selection Rate
	Submitted	Awarded	
2010	14	3	21%
2011	24	5	21%
2012	13	3	23%
2013	Not Solicited	N/A	N/A
2014	14	5	36%
2015	12	2	17%
Total to Date	77	18	23%

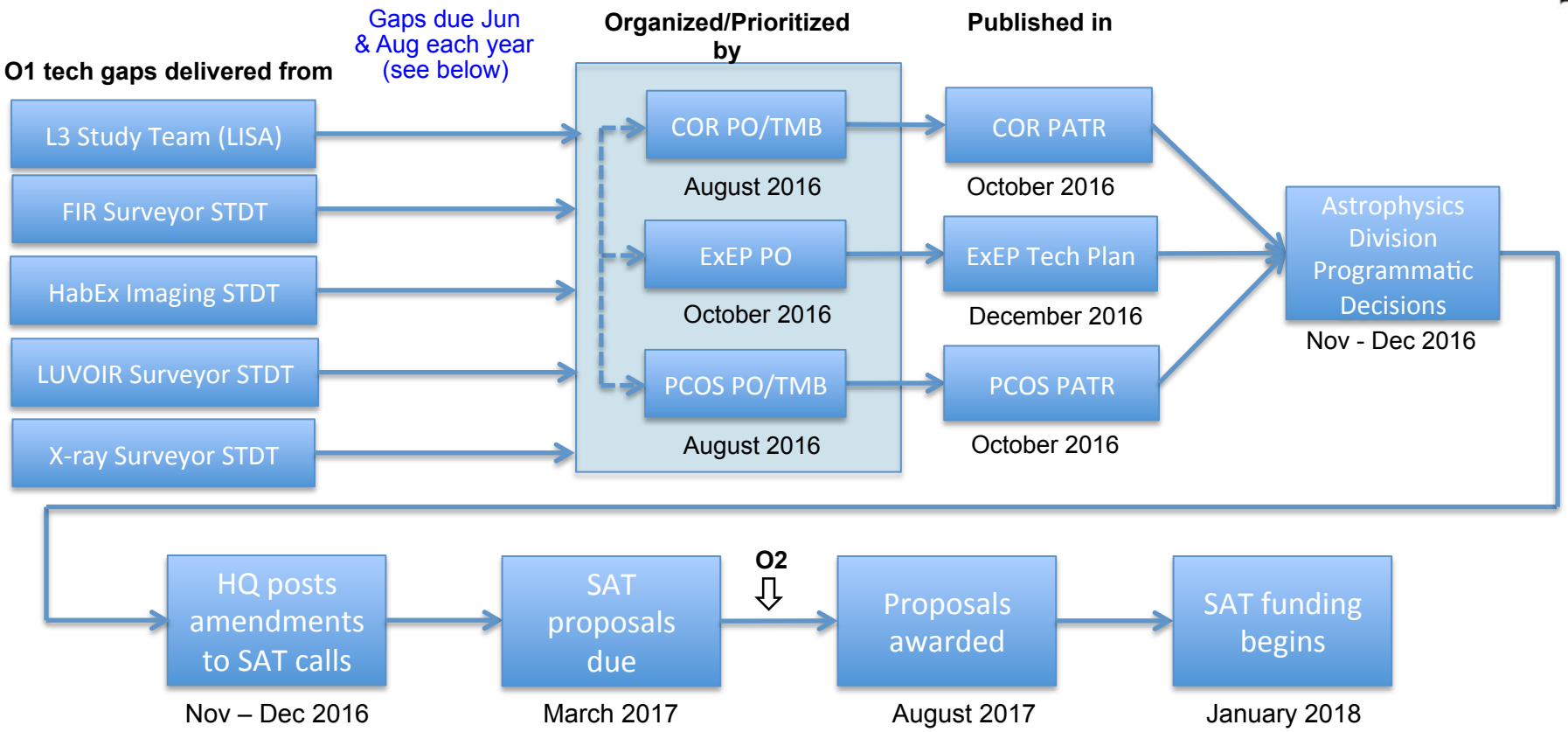
Strategic Technology Development Process



Process is responsive to community input and informs strategic technology investments for the program and beyond

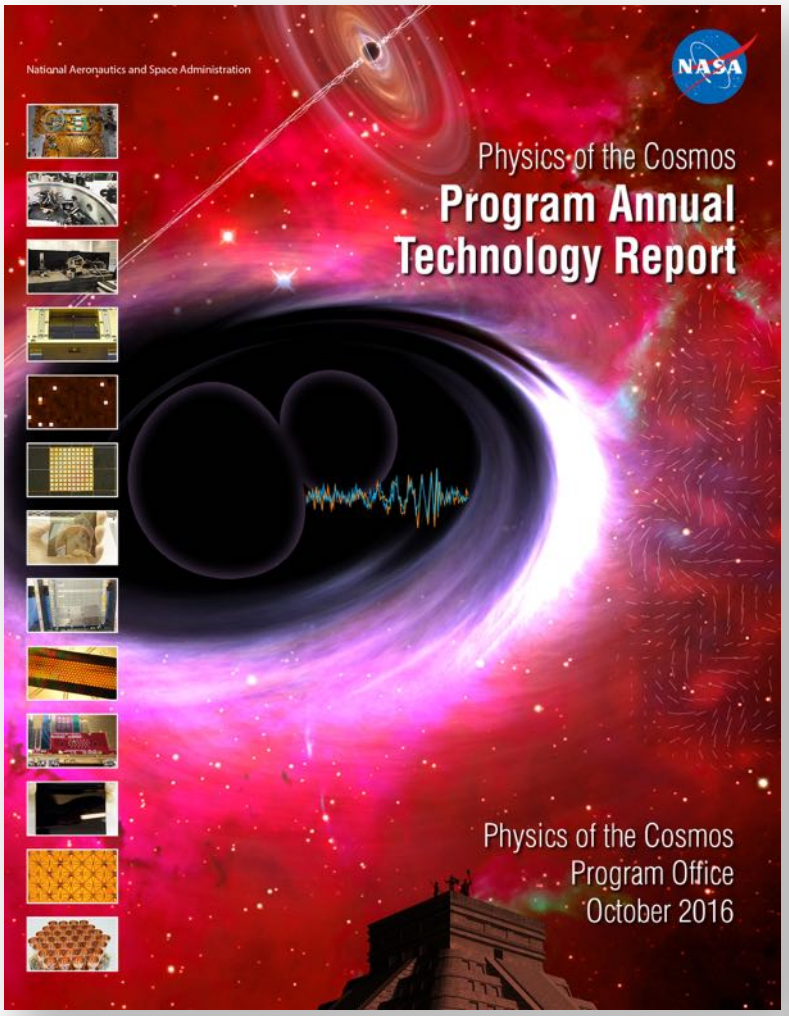
Program Annual Technology Report = PATR

Astrophysics Technology Gap Process and 2016 SAT Timeline



- Non-Exoplanet-related gaps due June; Exoplanet-related gaps due August.
- Community technology gap inputs are also provided to the respective Program Offices (POs) to be prioritized each year by the Programs' Technology Management Boards (TMBs) for COR and PCOS and by the ExEP PO.
- Program Chief Technologists participate in each other's technology prioritization processes.
- Current Program Annual Technology Reports (PATRs) and Technology Plan are available at pcos.gsfc.nasa.gov , cor.gsfc.nasa.gov , https://exoplanets.nasa.gov/exep/technology/technology-overview/
- Gaps identified in O2 (6/2017) Study Deliverable can also influence the 2016 SAT funding or directed funding.
- SAT funding nominally starts in January but could be ±3 months depending on receiving organization.

2016 PCOS and COR PATRs



Available at Program websites (pcos.gsfc.nasa.gov and cor.gsfc.nasa.gov)

Overview of Technology Gap Identification and Prioritization Process

- **Two routes for technology gap input by June 30:**
  - From the general community via the relevant Program Analysis Group (PAG) or through direct individual submission to the Program Office
  - Via the four strategic mission STDTs and L3ST
- **The Technology Management Board (TMB) reviews and prioritizes community-identified gaps in July**
  - TMB membership includes senior members of NASA HQ Astrophysics Division and its Program Offices, and as required, independent subject matter experts
  - Technology gap prioritization is based on a published set of criteria that addresses **scientific priorities, benefits and impacts, scope of applicability, and urgency**
- **The technology gaps and resulting priorities are published in the PATRs, released each October**

Objectives and Purposes of Technology Gap Prioritization

Objectives

- Identify technology gaps applicable and relevant to Program strategic objectives as described in the Astrophysics Implementation Plan (AIP)
- Rank technology gaps, recommending investment priorities

Purposes

- Inform the SAT solicitation and other NASA technology development programs (APRA, SBIR, and other OCT and STMD activities)
- Inform technology developers of Program gaps to help focus efforts
- Inform selection of technology awards to be aligned with Program goals and science objectives
- Improve transparency and relevance of Program technology investments
- Inform and engage the community in our technology development process
- Leverage technology investments of external organizations by defining our strategic technology gaps and identifying NASA as a potential customer

PCOS 2016 Technology Gaps Prioritization

	PCOS Capability Gaps	Science	Tech
1	Highly stable low-stray-light telescope	GW	Telescope
	High-power, narrow-line-width laser sources	GW	Laser
	Low-mass, long-term-stability optical bench	GW	Optical Bench
	Phase measurement system (PMS)	GW	Electronics
	Fast, low-noise, megapixel X-ray imaging arrays with moderate spectral resolution	X ray	Detector
	High-resolution, lightweight X-ray optics	X ray	Optics
2	Precision microthrusters	GW	Propulsion
	Non-contact charge control for gravitational reference sensors (GRS)	GW	Electronics
	Advanced millimeter-wave focal plane arrays for CMB polarimetry	CMB	Detector
	Millimeter-wave optical elements	CMB	Optics
	Large-format, high-spectral-resolution, small-pixel X-ray focal plane arrays	X ray	Detector
	High-efficiency X-ray grating arrays for high-resolution spectroscopy	X ray	Optics
	Rapid readout electronics for X-ray detectors	X ray	Electronics
	High-efficiency cooling systems for temperatures covering the range 20 K to below 1 K	X ray, CMB	Cooler
3	High-performance gamma-ray telescope	Gamma Ray	Telescope
	Gravitational reference sensor (GRS)	GW	Detector
	Lattice optical clock for Solar Time Delay (STD) mission and other applications	STD	Electronics
	Fast, few-photon UV detectors	UHECR	Detector
	Lightweight, large-area reflective optics	UHECR	Optics
	Low-power time-sampling readout	UHECR	Electronics
	Low-power comparators and logic arrays	UHECR	Electronics
	Low-stress or stress-free coating for X-ray optics	X ray	Coating
	Ultra-high-resolution focusing X-ray observatory telescope	X ray	Telescope
	Very-wide-field focusing instrument for time domain X-ray astronomy	X ray	Optics
	Advancement of X-ray polarimeter sensitivity using negative ion gas	X ray	Detector

PCOS Priority 1
Technology Areas to Enable Strategic Missions

- **Supporting NASA contribution to ESA's LISA mission**
  - Stable, low light-level telescope
  - Lasers used for precision interferometric metrology
  - High-stability optical bench
  - Phase measurement system

- **Supporting a future x-ray flagship mission**
  - High-resolution optics
  - Fast, low-noise, megapixel X-ray imaging arrays with moderate spectral resolution

See PCOS PATR for more information about these technology gaps

PCOS Priority 2
Technology Areas to Enable Missions of All Types

- **Supporting NASA contribution to ESA's LISA mission**
  - Precision microthrusters
  - Non-contact charge control for gravitational reference sensors
- **Millimeter-wave optical and detector components**
  - Advanced millimeter-wave focal plane arrays for CMB polarimetry
  - Millimeter-wave optical elements
- **X-ray optical and detector components**
  - Large-format, high-spectral-resolution, small-pixel X-ray focal plane arrays
  - High-efficiency X-ray grating arrays for high-resolution spectroscopy
  - Rapid readout electronics for X-ray detectors
  - High-efficiency cooling systems for temperatures covering the range 20 K to below 1 K (X-ray and CMB missions)

See PCOS PATR for more information about these technology gaps

COR 2016 Technology Gaps Prioritization

	COR Capability Gaps	Science	Tech
1	Large-format, low-noise and ultralow noise Far-IR direct detectors	FIR	Detector
	Heterodyne Far-IR detector arrays and related technologies	FIR	Detector
	Large cryogenic optics for the Far-IR	FIR	Optics
	High-performance, sub-Kelvin coolers	FIR	Cooler
	Compact, integrated spectrometers for 100 to 1000 μm	FIR	Detector
	Large-format, high-sensitivity, high-dynamic-range UV/FUV detectors	UV/FUV	Detector
	High-efficiency UV multi-object spectrometers	UV	Detector
	Band-shaping and dichroic filters for the UV/Vis	UV/Vis	Optics
	Lightweight large-aperture high-performance telescope mirror systems	UV/Vis/IR	Optics
2	Advanced Cryocoolers	FIR	Cooler
	Mid-IR spectral coronagraph	Mid-IR	Optics
	High-performance spectral dispersion component/device	UV/Vis/IR, FIR	Optics
	High-reflectivity mirror coatings for UV/Vis/NIR	UV/Vis/IR	Coating
	High-contrast segmented aperture coronagraphy	UV/Vis/IR	Optics
	Ultra-stable opto-mechanical systems	UV/Vis/IR	Telescope
	Very-large-format, high-QE, low-noise, radiation-tolerant detectors for UV/Vis/NIR	UV/Vis/IR	Detector
3	Wide-bandwidth, high-spectral-dynamic-range receiving system	Radio	Detector
	FIR interferometry	FIR	Detector

COR Priority 1
Technology Areas to Enable Strategic Missions

- **Supporting a far-IR/sub-mm strategic mission**
  - Large-format, low-noise and ultra low-noise far-IR direct detectors
  - Heterodyne far-IR detector arrays and related technologies
  - Large cryogenic optics for the far-IR
  - High-performance, sub-Kelvin coolers
  - Compact, integrated spectrometers for 100 to 1000 µm

- **Supporting a UVOIR strategic mission**
  - Large-format, high-sensitivity, high-dynamic-range UV/FUV detectors
  - High-efficiency UV multi-object spectrometers
  - Band-shaping and dichroic filters for the UV/Vis
  - Lightweight large-aperture high-performance telescope mirror systems

See COR PATR for more information about these technology gaps

COR Priority 2
Technology Areas to Enable Missions of All Types

- **Enabling far- and mid-IR observatories of all types**
  - Advanced cryocoolers
  - Mid-IR spectral coronagraph
  - High-performance spectral dispersion component/device

- **Enabling UVOIR observatories of all types**
  - High-performance spectral dispersion component/device
  - High-reflectivity mirror coatings for UV/Vis/NIR
  - High-contrast segmented aperture coronagraphy
  - Ultra-stable opto-mechanical systems
  - Very-large-format, high-QE, low-noise, radiation-tolerant detectors for UV/Vis/NIR

See COR PATR for more information about these technology gaps

Current PCOS SAT Portfolio

Funding Source	Technology Development Title	Principal Investigator	Org	Start Year, Duration	Science Area	Tech Area
SAT2010	Directly-Deposited Blocking Filters for Imaging X-ray Detectors: Technology Development for the International X-ray Observatory	Mark Bautz	MIT	FY2012, 4 years	X-ray	Detector
SAT2012	Phase Measurement System Development for Interferometric Gravitational Wave Detectors	William Klipstein	JPL	FY2014, 3 years	GW	Electronics
SAT2012	Demonstration of a TRL 5 Laser System for eLISA	Jordan Camp	GSFC	FY2014, 2 years	GW	Laser
SAT2013 SAT2010	Reflection Grating Modules: Alignment and Testing	Randy McEntaffer	U. of Iowa	FY2015, 2 years	X-ray	Optics
SAT2013 SAT2010	Advanced Packaging for Critical Angle X-ray Transmission Gratings	Mark Schattenburg	MIT	FY2015, 2 years	X-ray	Optics
SAT2013	Technology Development for an AC-Multiplexed Calorimeter for ATHENA	Joel Ullom	NIST	FY2015, 2 years	X-ray	Detector
SAT2013 APRA2011	Development of 0.5 Arc-second Adjustable Grazing Incidence X-ray Mirrors for the SMART-X Mission Concept	Paul Reid	SAO	FY2015, 3 years	X-ray	Optics
SAT2013 SAT2011	Affordable and Lightweight High-Resolution Astronomical X-Ray Optics	William Zhang	GSFC	FY2015, 2 years	X-ray	Optics
SAT2013	Fast Event Recognition for the ATHENA Wide Field Imager	David Burrows	PSU	FY2015, 2 years	X-ray	Detector
SAT2014 SAT2012 SAT2010	Superconducting Antenna-Coupled Detectors and Readouts for Space-Borne CMB Polarimetry	Jamie Bock	JPL	FY2016, 2 years	CMB	Detectors
SAT2014 & SAT2011	Telescope Dimensional Stability Study for a Space-based Gravitational Wave Mission	Jeffrey Livas	GSFC	FY2016, 2 years	GW	Telescope
SAT2014	High Efficiency Feedhorn-Coupled TES-based Detectors for CMB Polarization Measurements	Edward Wollack	GSFC	FY2016, 2 years	CMB	Detector
Directed 2016	Providing Enabling and Enhancing Technologies for a Demonstration Model of the Athena X-IFU	Caroline Kilbourne	GSFC	FY2016, 2 years	X-ray	Detector

Current COR SAT Portfolio

Funding Source	Technology Development Title	Principal Investigator	Org	Start Year, Duration	Science Area	Tech Area
SAT2011	Ultraviolet coatings, materials and processes for advanced telescope optics	Kunjithapatham Balasubramanian	JPL	FY2013, 3 years	UV	Optical Coating
SAT2011	Kinetic Inductance Detector Imaging Arrays for Far-Infrared Astrophysics	Jonas Zmuidzinas	JPL	FY2013, 3 years	Far-IR	Detector
SAT2012	A Far-Infrared Heterodyne Array Receiver for CII and OI Mapping	Imran Mehdi	JPL	FY2014, 3 years	Far-IR	Detectors
SAT2012	Deployment of Digital Micromirror Device (DMD) Arrays For Use In Future Space Missions	Zoran Ninkov	RIT	FY2014, 2 years	UV	Detector
SAT2012 & SAT2010	Advanced Mirror Technology Development Phase 2	Phil Stahl	MSFC	FY2014, 3 years	UVOIR	Optics
SAT2014	Raising the Technology Readiness Level of 4.7-THz local oscillators	Qing Hu	MIT	FY2016, 3 years	Far-IR	Detector
SAT2014 & SAT2010	Development of Large Area (100x100 mm) photon counting UV detectors	John Vallerga	UCB	FY2016, 2 years	UV	Detector
SAT2014	Building a Better ALD - use of Plasma Enhanced ALD to Construct Efficient Interference Filters for the FUV	Paul Scowen	ASU	FY2016, 3 years	UV	Optical Coating
SAT2014 & SAT2011	Advanced FUVUV/Visible Photon Counting and Ultralow Noise Detectors	Shouleh Nikzad	JPL	FY2016, 3 years	UVOIR	Detector
SAT2014	Ultra-Stable Structure: Development and Characterization Using Spatial Dynamic Metrology	Babak Saif	GSFC	FY2016, 4 years	UVOIR	Stable Structure
SAT2015	High-Efficiency Continuous Cooling for Cryogenic Instruments and sub-Kelvin Detectors	James Tuttle	GSFC	FY2017, 3 years	Far-IR	Cooling System
SAT2015	Predictive Thermal Control Technology for Stable Telescope	H. Philip Stahl	MSFC	FY2017, 3 years	UVOIR	Optics

How You Can Participate

- Engage your science and technology communities
- Visit the PCOS and COR websites for more information
- Subscribe to the PCOS and COR mailing lists and receive news and announcements to stay informed (from websites below)
- Participate/contribute to STDT activities
- Attend PAG meetings (in person or remotely) and participate in PAG activities
- Contribute to technology gaps list by submitting your input(s)
- Read and comment on the PATRs
- Propose to SAT and APRA proposal calls through NSPIRES
  - Notices of Intent to propose are due January 20, 2017
  - Proposals are due March 17, 2017
- Feel free to contact us if you have any questions

pcos.gsfc.nasa.gov / cor.gsfc.nasa.gov

Takeaways

- **Currently the process described here is main technology development pathway for APD to mature technologies.**

- **PCOS and COR Program Offices solicit community input on technology gaps throughout the year**
  - Submit technology gaps by June for next year's consideration
- **Technology gap priorities are published each October in the PATR**
  - Consult these reports to learn what strategic technologies are needed by the PCOS and COR programs
- **Contribute and engage with your science communities to help shape future missions**
  - Participate in PAG and STDT meetings and activities
  - Propose your innovations!

Thank You for Listening